

CLAIMS

- 1 1. A dynamic optical add/drop multiplexer comprising:
 - 2 a single substrate;
 - 3 a first optical circulator having a first port to receive a multiple wavelength
 - 4 optical signal, a second port to output the received multiple wavelength optical signal,
 - 5 and a third port;
 - 6 a tunable reflective filter connected to the second port of the first circulator to
 - 7 receive the optical signal wherein the filter segregates a tuned wavelength from the
 - 8 optical signal and reflects the tuned wavelength back to the first circulator, which outputs
 - 9 the tuned wavelength via the third port;
 - 10 a second optical circulator having a first port to receive the optical signal from the
 - 11 filter, a second port to receive an add optical signal comprising the same wavelength as
 - 12 the tuned wavelength, and a third port to output the multiple wavelength optical signal
 - 13 and the add optical signal; and
 - 14 wherein the first circulator, second circulator and tunable reflective filter are all
 - 15 formed on the single substrate.
- 1 2. A dynamic optical add/drop multiplexer, as per claim 1, wherein the tunable reflective
 - 2 filter is a tunable Bragg grating.
- 1 3. A dynamic optical add/drop multiplexer, as per claim 1, wherein the first and second
 - 2 circulator are based on planar Mach-Zehnder interferometers using either polarization splitting

and nonreciprocal polarization conversion, or nonreciprocal phase shift within the interferometric arms.

4. A trimmable MZI-based dynamic optical add/drop multiplexer comprising:

a first optical path having a tunable reflective filter formed therein;

a first phase shifter associated with the first optical path;

a second optical path having a tunable reflective filter formed therein;

a second phase shifter associated with the second optical path;

a first 3dB coupler having a first port to receive a multiple wavelength optical signal and substantially evenly split the signal into the first optical path and the second optical path wherein the tunable reflective filters of the first and second paths segregate a tuned wavelength from the split optical signal and reflect the tuned wavelength back to the first 3dB coupler, which outputs the tuned wavelength via a second port;

a second 3dB coupler to receive the split optical signal from the first and second optical paths and to combine the split signal into a single signal output via a first port, the second 3dB coupler having a second port to receive an add optical signal comprising the same wavelength as the tuned wavelength wherein the add optical signal is additionally output via the first port;

wherein the optical lengths of the first and second optical path are balanced by the phase shifters.

5. A trimmable MZI-based dynamic optical add/drop multiplexer, as per claim 1, wherein the first and second couplers are directional couplers.

- 1 6. A trimmable MZI-based dynamic optical add/drop multiplexer, as per claim 4, wherein
2 the couplers are MMI based couplers.
- 1 7. A trimmable MZI-based dynamic optical add/drop multiplexer, as per claim 4, wherein
2 the couplers are MZI-based couplers.
- 1 8. A trimmable MZI-based dynamic optical add/drop multiplexer, as per claim 4, wherein
2 the tunable reflective filter is a tunable Bragg grating.
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9. An optical device comprising:
a first directive coupler having a first port to receive a multiple wavelength
optical signal, a second port to output the received multiple wavelength optical signal,
and a third port;
a tunable reflective filter connected to the second port of the first directive
coupler to receive the optical signal wherein the filter segregates a tuned wavelength
from the optical signal and reflects the tuned wavelength back to the first directive
coupler, which outputs the tuned wavelength via the third port;
a second directive coupler having a first port to receive the optical signal from the
filter, a second port to output the multiple wavelength optical signal, and a third port,
wherein any optical signals input the third port are output via the first port;
a switch having an input port connected to the third port of the first directive
coupler to receive the tuned wavelength, a first output port connected to the third port of
the second directive coupler, and a second output port;

the switch in a first state causes the tuned wavelength to be output to the third port of the second directive coupler via the first output port of the switch; and the switch in a second state causes the tuned wavelength to be output via the second output port of the switch.

10. An optical device, as per claim 9, wherein the switch is a cross bar switch further having an add port;

the switch in the first state further causes an add optical signal input to the add port to be output via the second output port of the switch, the add optical signal comprising the same wavelength as the tuned wavelength; and

the switch in the second state further causes an add optical signal input to the add port to be output to the third port of the second directive coupler via the first output port of the switch, the add optical signal comprising the same wavelength as the tuned wavelength.

11. An optical device, as per claim 10, wherein the optical device is a hitless dynamic optical add/drop multiplexer.

12. An optical device, as per claim 11, wherein the tunable reflective filter is a tunable Bragg grating.

13. An optical device, as per claim 11, wherein the first and second directive couplers are optical circulators.

1 14. An optical device, as per claim 13, wherein the tunable reflective filter and the cross bar
2 switch are formed on the same substrate.

1 15. An optical device, as per claim 13, wherein the tunable reflective filter, the cross bar
2 switch and the optical circulators are formed on the same substrate.

1 16. An optical device, as per claim 11, wherein:

2 the tunable reflective filter comprises a single Bragg grating spanning two optical
3 paths;

4 the first directive coupler comprises a 3dB coupler connected to the two optical
5 paths so as to substantially evenly split the multiple wavelength optical signal into both
6 optical paths; and

7 the second directive coupler comprises a 3dB coupler receiving the split optical
8 signal from the two optical paths.

9 17. A multi-channel hitless optical add/drop multiplexer comprising a cascade of hitless
2 dynamic optical add/drop multiplexers according to claim 10.

1 18. A multi-channel hitless optical add/drop multiplexer, as per claim 9, wherein the optical
2 device is a hitless dynamic multiplexer/demultiplexer.

1 19. An optical device comprising:

2 a first and second directive coupler having at least one tunable reflective filter
3 connected therebetween, the first directive coupler having a first port to receive a

multiple wavelength optical signal, a second port to output the received multiple wavelength optical signal to the at least one filter, and a third port, the filter segregates a tuned wavelength from the optical signal and reflects the tuned wavelength back to the first directive coupler, which outputs the tuned wavelength via the third port, the second directive coupler having a first port to receive the optical signal from the filter, a second port to output the multiple wavelength optical signal, and a third port, wherein any optical signals input the third port are output via the first port;

a third and fourth directive coupler having at least one tunable reflective filter connected therebetween, the third directive coupler having a first port to receive a multiple wavelength optical signal, a second port to output the received multiple wavelength optical signal to the at least one filter, and a third port, the filter segregates at least one tuned wavelength from the optical signal and reflects the tuned wavelength back to the third directive coupler, which outputs the tuned wavelength via the third port, the fourth directive coupler having a first port to receive the optical signal from the filter, a second port to output the multiple wavelength optical signal, and a third port, wherein any optical signals input the third port are output via the first port; and

a cross bar switch, the cross bar switch in a first state connects the third port of the first directive coupler to the third port of the fourth directive coupler and connects the third port of the third directive coupler to the third port of the second directive coupler, the cross bar switch in a second state connects the third port of the first directive coupler to the third port of the second directive coupler and connects the third port of the third directive coupler to the third port of the fourth directive coupler.

1 20. A optical device, as per claim 19, wherein the at least one filter connected between the
2 first and second directive couplers comprises a plurality of tunable reflective filters and the at
3 least one filter connected between the second and third directive couplers comprises a plurality
4 of tunable reflective filters.

1 21. A hitless dynamic wavelength selective switch comprising a cascade of optical devices
2 according to claim 19.

1 22. An hitless dynamic optical cross connect comprising a cascade of optical devices
according to claim 19.

1 23. A hitless errorless dynamic optical add/drop multiplexer comprising:
2 a first optical circulator having a first port to receive a multiple wavelength
3 optical signal, a second port to output the received multiple wavelength optical signal,
4 and a third port;
5 a first switch having an input port, a first output port, and a second output, the
6 input port connected to the second port of the first circulator;
7 a filter path comprising a tunable reflective filter connected to the first output port
8 of the first switch;
9 a bypass path comprising an optical path connected to the second output port of
10 the first switch;
11 a second switch having a first input port connected to the filter path, a second
12 input port connected to the optical path, and an output port;

the first and second switch in a first state causes the optical signal to be directed along the filter path wherein the reflective filter segregates a tuned wavelength from the optical signal and reflects the tuned wavelength back to the first circulator, which outputs the tuned wavelength via the third port;

the first and second switch in a second state cause the optical signal to be directed along the bypass path which leaves the optical signal substantially unaffected; and

a second optical circulator having a first port connected to the output port of the second switch to receive the optical signal from the second switch, a second port to output the optical signal and a third port to receive an add optical signal, the add optical signal comprising the same wavelength as the tuned wavelength, the add optical signal output via the second port with the optical signal.

24. A hitless errorless dynamic optical add/drop multiplexer according to claim 23 formed on a single substrate.

25. A multi-channel hitless errorless dynamic optical add/drop multiplexer comprising a cascade of hitless errorless dynamic optical add/drop multiplexers according to claim 23.

26. A polarization independent hitless dynamic errorless optical add/drop multiplexer comprising:

a first hitless dynamic errorless optical add drop multiplexer according to claim 23;

a second hitless dynamic errorless optical add drop multiplexer according to claim 23;

a first polarization splitter having an input port, a first output port connected to the first port of the first circulator of the first multiplexer, and a second output port connected to the first port of the first circulator of the second multiplexer;

a first polarization combiner having an output port, a first input port connected to the third port of the first circulator of the first multiplexer, and a second input port connected to the third port of the first circulator of the second multiplexer;

a second polarization splitter having an input port, a first output port connected to the third port of the second circulator of the first multiplexer, and a second output port connected to the third port of the second circulator of the second multiplexer; and

a second polarization combiner having an output port, a first input port connected to the second port of the second circulator of the first multiplexer, and a second input port connected to the second port of the second circulator of the second multiplexer.

27. A multistage polarization independent hitless dynamic errorless add/drop multiplexer that operates over a specified optical spectrum, the multiplexer comprising:

a first polarization independent hitless dynamic errorless optical add/drop multiplexer according to claim 26 that operates over a portion of the specified spectrum;

a second polarization independent hitless dynamic errorless optical add/drop multiplexer according to claim 26 that operates over a portion of the specified spectrum different from the portion the first multiplexer operates on;

a first switch having an input port, a first output port connected to the input port of the first polarization splitter of the first polarization independent hitless dynamic errorless optical add/drop multiplexer, a second output port connected to the input port of the first polarization splitter of the second polarization independent hitless dynamic errorless optical add/drop multiplexer;

a second switch having an output port, a first input port connected to the output port of the first polarization combiner of the first polarization independent hitless dynamic errorless optical add/drop multiplexer, a second input port connected to the output port of the first polarization splitter of the second polarization independent hitless dynamic errorless optical add/drop multiplexer;

a third switch having an input port, a first output port connected to the input port of the second polarization splitter of the first polarization independent hitless dynamic errorless optical add/drop multiplexer, a second output port connected to the input port of the second polarization splitter of the second polarization independent hitless dynamic errorless optical add/drop multiplexer;

a fourth switch having an output port, a first input port connected to the output port of the second polarization combiner of the first polarization independent hitless dynamic errorless optical add/drop multiplexer, a second input port connected to the output port of the second polarization splitter of the second polarization independent hitless dynamic errorless optical add/drop multiplexer.

28. A hitless errorless dynamic optical add/drop multiplexer comprising:

2 a first optical path having a tunable reflective filter formed therein;

3 a second optical path having a tunable reflective filter formed therein;

4 a first switch having an input port to receive a multiple wavelength optical signal,
5 a first output port to output the optical signal when the first switch is in a first state, and a
6 second output port to output the optical signal when the first switch is in a second state;

7 a first 3dB coupler having a first port connected to the second output port of the
8 first switch to receive the multiple wavelength optical signal and substantially evenly
9 split the signal into the first optical path and the second optical path wherein the tunable
10 reflective filters of the first and second paths segregate a tuned wavelength from the split
11 optical signal and reflect the tuned wavelength back to the first 3dB coupler, which
12 outputs the tuned wavelength via a second port;

13 a second 3dB coupler to receive the split optical signal from the first and second
14 optical paths and to combine the split signal into a single signal output via a first port, the
15 second 3dB coupler having a second port to receive an add optical signal comprising the
16 same wavelength as the tuned wavelength wherein the add optical signal is additionally
17 output via the first port; and

18 a second switch having a first input port connected to the first port of the second
19 3dB coupler to receive the optical signals, a second input port operatively connected to
20 the second output port of the first switch by a bypass optical path, and an output port to
21 output optical signals from the second 3dB coupler when the second switch is in a first
22 state and to output optical signals from the bypass optical path when the second switch is
23 in a second state.

1 29. A hitless errorless dynamic optical add/drop multiplexer, as per claim 28, wherein the
2 first and second switches are directional couplers.

1 30. A hitless errorless dynamic optical add/drop multiplexer, as per claim 28, wherein the
2 first and second switches are MMI-based switches.

1 31. A hitless errorless dynamic optical add/drop multiplexer, as per claim 28, wherein the
2 first and second switches are MZI-based switches.

1 32. A multi-channel hitless errorless dynamic optical add/drop multiplexer comprising a
2 cascade of hitless errorless dynamic optical add/drop multiplexers according to claim 28.

1 33. A polarization independent hitless dynamic errorless optical add/drop multiplexer
2 comprising:

3 a first hitless dynamic errorless optical add drop multiplexer according to claim
4 28;

5 a second hitless dynamic errorless optical add drop multiplexer according to
6 claim 28;

7 a first polarization splitter having an input port, a first output port connected to
8 the input port of the first switch of the first multiplexer, and a second output port
9 connected to the input port of the first switch of the second multiplexer;

10 a first polarization combiner having an output port, a first input port connected to
11 the second port of the first 3dB coupler of the first multiplexer, and a second input port
12 connected to the second port of the first 3dB coupler of the second multiplexer;

a second polarization splitter having an input port, a first output port connected to the second port of the second 3dB coupler of the first multiplexer, and a second output port connected to the second port of the second 3dB coupler of the second multiplexer; and

a second polarization combiner having an output port, a first input port connected to the output port of the second switch of the first multiplexer, and a second input port connected to the output port of the second switch of the second multiplexer.

34. A multistage polarization independent hitless dynamic errorless add/drop multiplexer that operates over a specified optical spectrum, the multiplexer comprising:

a first polarization independent hitless dynamic errorless optical add/drop multiplexer according to claim 33 that operates over a portion of the specified spectrum;

a second polarization independent hitless dynamic errorless optical add/drop multiplexer according to claim 33 that operates over a portion of the specified spectrum different from the portion the first multiplexer operates on;

a first switch having an input port, a first output port connected to the input port of the first polarization splitter of the first polarization independent hitless dynamic errorless optical add/drop multiplexer, a second output port connected to the input port of the first polarization splitter of the second polarization independent hitless dynamic errorless optical add/drop multiplexer;

a second switch having an output port, a first input port connected to the output port of the first polarization combiner of the first polarization independent hitless

dynamic errorless optical add/drop multiplexer, a second input port connected to the output port of the first polarization splitter of the second polarization independent hitless dynamic errorless optical add/drop multiplexer;

a third switch having an input port, a first output port connected to the input port of the second polarization splitter of the first polarization independent hitless dynamic errorless optical add/drop multiplexer, a second output port connected to the input port of the second polarization splitter of the second polarization independent hitless dynamic errorless optical add/drop multiplexer;

a fourth switch having an output port, a first input port connected to the output port of the second polarization combiner of the first polarization independent hitless dynamic errorless optical add/drop multiplexer, a second input port connected to the output port of the second polarization splitter of the second polarization independent hitless dynamic errorless optical add/drop multiplexer.